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Effect of Sport-specific Demands On Swimmer's Shoulder

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EFFECT OF SPORT-SPECIFIC DEMANDS ON SWIMMER'S SHOULDER

by

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ABSTRACT

Effects of Sport-Specific Demands on Swimmer's Shoulder

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Swimming is a unique sport in that the shoulders generate most of the propulsive force. Therefore, due to the large amounts of repetitive force the shoulders generate during freestyle, swimmer's shoulder is the most common injury among competitive swimmers. Freestyle biomechanics, muscular imbalances and posture all play a pertinent role in a swimmer's risk for developing a shoulder injury during their swimming career. Swimmers typically develop large muscular imbalances between their dominant and non-dominant shoulders due to several sport-specific demands including freestyle stroke mechanics, breathing, and body roll. These muscular imbalances alter a swimmer's posture and freestyle biomechanics which eventually lead to shoulder pain or injury. Understanding the effects of sport-specific demands on stroke biomechanics, posture, and muscular imbalances may provide a way to improve shoulder mechanics in the water, allow for preventative measures to be taken early on in a swimmer's career, and ultimately decrease the swimmer's risk of developing swimmer's shoulder.

KEYWORDS: Swimmer's Shoulder, Biomechanics, Breathing, Posture, Prevention

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Many individuals swim for recreation and exercise around the world. The sport of swimming has drastically changed since it was first introduced as an Olympic sport during the 1896 summer games. Since then, swimming has essentially developed into a year-round sport with a large training load even during the off-season. Most competitive swimmers practice five to seven days per week and sometimes twice a day. To swim at an elite level, swimmers typically swim anywhere from 60,000 to 80,000 meters per week, which is approximately 30,000 strokes per arm (Matzkin, Suslavich, & Wes, 2016). The repetitive nature of the freestyle stroke and the demanding training programs raise several concerns regarding potential shoulder injuries. Freestyle biomechanics, muscular imbalances, and posture play a pertinent role in a swimmer's risk for a shoulder injury.

Swimming is a unique sport because the upper body generates most of the propulsive force, with 90% of the driving force generated by the shoulders (Pink & Tibone, 2000). Due to the large amounts of repetitive force exerted by the shoulder, swimmer's shoulder is the most common injury affecting approximately 40% - 91% of competitive swimmers (Pink & Tibone, 2000). Also, 60% of swimmers develop shoulder pain in their dominant shoulder at some point in their swimming career (Richardson, Jobe, & Collins, 1980). Swimmer's shoulder is a broad diagnosis for shoulder pain among competitive swimmers due to the repeated abduction and forward flexion of the shoulder during the freestyle stroke. The broad diagnosis of swimmer's shoulder consists of several injuries including subacromial impingement, scapular dyskinesis, shoulder hyperlaxity, glenohumeral internal rotation deficit, subscapular neuropathy, subluxation, and os acromiale. Understanding the effects of freestyle biomechanics on the shoulder and posture can help coaches be proactive by emphasizing preventative measures from a young age.

CHAPTER 2

REVIEW OF LITERATURE

Biomechanical Aspects

There are three main biomechanical aspects of swimming including stroke mechanics, breathing, and body position (i.e., body roll). The freestyle stroke can then be broken down into five different phases:

The Entry

During the entry phase, a swimmer's fingertips enter the water above the head and shoulder with the thumb rotated slightly downward. The fingertips enter the water first, then the wrist, the forearm, and the elbow follow to minimize the amount of drag (W. C. McMaster & Troup, 2001).

Down-Sweep (Catch)

The down-sweep is a non-propulsive phase as the forearm angles downward to catch the water (Pansiot, Lo, & Yang, 2010). During the down-sweep phase the wrist flexes approximately forty degrees, the palm rotates outward, and the hand presses downward and outward away from the shoulder joint (W. C. McMaster & Troup, 2001). Typically, swimmer’s hand-depth during the catch differs between men (0.6 meters) and women (0.8 meters) (Pansiot et al., 2010). To move your hand through the water at an increased depth the swimmer would need to generate more force than normal. Female swimmers also take shorter and a greater number of freestyle strokes compared to males (Pansiot et al., 2010). Therefore, female swimmers are at a greater risk for shoulder injury due to the increased hand-depth and shorter strokes as they are taking a greater number of strokes with a greater amount of force than male swimmers (Pansiot et al., 2010).

In-Sweep (Pull)

Next is a propulsive phase of freestyle, the in-sweep (Pansiot et al., 2010). During the in-sweep phase, the swimmer’s hand rotates inward and sweeps toward the midline of the swimmer’s body (W. C. McMaster & Troup, 2001). The in-sweep is also the narrowest part of the freestyle stroke.

Up-Sweep (Push)

The up-sweep phase is the propulsive motion of the arm past the shoulder joint until the arm exits from the water (Pansiot et al., 2010). In the up-sweep phase, the hand moves outward and backward away from the swimmer’s midline towards the water’s surface (W. C. McMaster & Troup, 2001).

Recovery

The final phase of the freestyle stroke is the recovery phase which consists of the aerial time between when the arm exits the water and enters again upon another stroke (Pansiot et al., 2010). At this point in the freestyle stroke, the elbow is bent, pointed upward towards the sky and relaxed (W. C. McMaster & Troup, 2001).

Body Roll

In addition to the five phases of freestyle, body roll is an important factor to consider when looking at risk for shoulder injury. Swimmers do not want excessive amounts of body roll, but they also don't want little body roll either. Optimally, a swimmer's body roll angle should range between 35° to 45° on each side (Vezos et al., 2007). Most swimmers tend to recover their arms higher on the breathing side than the non-breathing side. This causes the body to roll more toward their breathing side compared to their non-breathing side placing the shoulder in an unfavorable position, therefore increasing the risk for shoulder injury (Vezos et al., 2007). In addition, the excessive amounts of body roll can cause the swimmer's hand to cross the body's midline during the pull phase of freestyle. This causes an increase in shoulder horizontal adduction. On the other hand, a lack of body roll will also cause the shoulder to compensate by increasing the amount of horizontal adduction for adequate propulsion forward (Vezos et al., 2007).

Breathing

Breathing is an essential part of swimming biomechanics and is often overlooked. Ideally, swimmers should take their breath during the first half of the recovery phase, and their face should be returned to the water during the second half of the recovery phase (Vezos et al., 2007). During their breath, swimmers should avoid lifting their head out of the water. Lifting the head for a breath places unnecessary additional pressure on their shoulder (Vezos et al., 2007).

Unilateral vs. Bilateral Breathing

When swimming freestyle, swimmers may either breathe unilaterally or bilaterally. The majority of competitive swimmers only breathe to one side, unilaterally, during competition which then translates into practice, even with a coach's best efforts to avoid it. Swimmers who breathe unilaterally typically have a more asymmetric stroke pattern and an increased lag time between strokes. Whereas, swimmers who breathe to both sides display a more symmetrical stroke and do not have a noticeable lag time between strokes. The lag time refers to the amount of time spent in a gliding motion during a breath. The greater the lag time the longer the amount of time the swimmer spends in a gliding motion instead of propelling themselves forward. However, when breathing unilaterally, swimmers automatically adapt and learn to stabilize the breathing motion through a sculling motion with their dominant shoulder. This causes the lag time or gliding between subsequent strokes which places additional stress for a longer amount of time on the dominant shoulder (Seifert, Chollet, & Allard, 2005).

Analysis of Stroke Biomechanics

Painful Shoulder Positions

The shoulder is placed in a likely impingement position during 24.8% of the freestyle stroke including parts of the sweeping and the recovery phases (Heinlein & Cosgarea, 2010). The greatest amount of force is generated during the sweeping phases of freestyle when the shoulder is positioned at its maximal amount of internal rotation and horizontal abduction. Pain most commonly occurs within the three sweeping phases due to the sheer amount of force generated in an unstable position (Matzkin et al., 2016).

Another painful position for the shoulder is during the recovery phase because the shoulder is abducted and externally rotated to a large degree. Approximately half-way through the recovery phase is when maximal external shoulder rotation occurs. Hyperextension can also be painful when the forearm is swung forward for the arm to be at full extension for hand entry into the water (Matzkin et al., 2016).

Altered Stroke Mechanics Indicating Pain

There are a few common warning signs and alterations in a swimmer's stroke mechanics that are indicative of shoulder pain. It is imperative that coaches and athletic trainers to watch for these warning signs. Symptomatic swimmers typically place their arm farther from the midline during hand entry and in a dropped elbow position (Heinlein & Cosgarea, 2010). During freestyle, swimmers will drop their elbow to avoid the shoulder internal rotation found during the sweeping phases (Matzkin et al., 2016). A dropped elbow occurs when swimmers pull their hand backward in a relatively flat position, which limits the amount of water they catch during the pull-phase. Excessive body roll also signifies shoulder pain, as the swimmer’s hand will come out of the water with less hyperextension to avoid placing the humeral head at an anterior angle, that causes pain (Matzkin et al., 2016).

Analysis of Breathing Biomechanics

There are several effects of breathing on each of the five phases of freestyle. During the entry phase of freestyle, a swimmer’s shoulder experiences more flexion, abduction, and roll during the breathing when compared to non-breathing strokes

(McCabe, Sanders, & Psycharakis, 2015). The increased shoulder flexion, abduction, and body roll during breathing strokes, decreases shoulder stability; therefore the shoulder is placed in a more stable and stronger position during non-breathing strokes. (Weldon & Richardson, 2001).

When a swimmer takes a breath the pull phase experiences a longer duration and shallower hand path. On average, the pull phase is 14% shorter during non-breathing strokes compared to breathing strokes (McCabe et al., 2015). When swimmers rotate their head to the side to breathe, the increase in pull time allows adequate time for the swimmer to inhale (Vezos et al., 2007). Therefore, swimmers place pressure on their fully extended shoulder (i.e., non-breathing side) for a longer period of time when breathing. In turn, this places the shoulder joint in an unstable position for an extended period of time, therefore increasing injury risk.

On the other hand, the push phase is typically shorter in duration and has less elbow extension during breathing strokes (McCabe et al., 2015). Ideally, swimmers want a greater amount of elbow extension to increase their efficiency and speed. This is why sprinters try to limit the number of breaths they take during their events. However, due to this lack of range of motion during breathing strokes, the swimmers spend 16% less time in the push-phase of freestyle. This, in turn, hinders their overall efficiency and speed (McCabe et al., 2015).

Not only does taking a breath alter the phases of freestyle, it also alters the swimmer's amount of body roll. To take a breath, swimmers roll their shoulders and hips earlier and to a greater degree on their breathing side (Psycharakis & McCabe, 2011). A swimmer's body roll increases by approximately 12% during breathing strokes (McCabe et al., 2015). This large amount of body roll creates a lag time between subsequent strokes to allow for a breath. Not only does this lag time allow swimmers to take a breath, but it also allows swimmers to create more propulsion with their dominant shoulder (Pansiot et al., 2010). Compared to bilateral breathing, unilateral breathing produces asymmetries between the dominant and non-dominant shoulders (Seifert et al., 2005).

During a breath, the dominant shoulder is in full extension underneath the swimmer's head, while the non-dominant shoulder is in the entry phase of freestyle. When breathing unilaterally, the dominant shoulder not only supports the breath, but causes asymmetrical coordination and propulsion (Tourney-Chollet, Seifert, & Chollet, 2009). Even though the non-dominant shoulder has a quicker hand path through the water, it will still produce less force than the dominant shoulder. Due to the long period of forward extension, the dominant shoulder has a longer period of time to apply a propulsive force which in turn generates more power (Tourney-Chollet et al., 2009). The elevated position of a sprinter's head during a breath increases the amount of demand placed on the internal rotators and adductors of the dominant shoulder (C. Tourney-Chollet, 2009). Due to this, 66% of the time, swimmers develop pain in their dominant shoulder (Richardson et al., 1980). Therefore, swimmers should avoid picking their head up to breathe to avoid adding any unnecessary demands to the shoulder. Swimmers who breathe bilaterally seem to have a better distribution of power between the dominant and non-dominant shoulders than those who breathe unilaterally. To prevent shoulder injury, bilateral breathing should be emphasized during practice to avoid placing more demand on one shoulder over the other.

Posture

Swimmers typically have a more rounded forward posture due to the demands of the sport. Forward posture occurs when the head is forward, the cervical spine is hyperextended, the thoracic spine is in slight flexion and the lumbar spine is in slight extension. This forward posture is due to muscular imbalances in the shoulders (Batalha et al., 2013). A swimmer's internal rotation strength is significantly greater than their external rotation strength as internal rotation is the primary movement during the propulsive phases of freestyle (Batalha, Raimundo, Tomas-Carus, Barbosa, & Silva, 2013). Therefore, when in a resting position the pectoralis minor pulls the swimmer's shoulders forward (Borstad, 2006). Swimming competitively from a young age and a large amount of water training tends to promote these muscular imbalances. Also, this forward posture decreases the subacromial space in the shoulder joint due to the increased anterior tilt and internal rotation of the scapula (Harrington, Melsel, & Tate, 2014). This anterior tilt and internal rotation of the scapula are greater in the overhead athlete's dominant shoulder than in the non-dominant shoulder (Oyama, Myers, Wassinge, Ricci, & Lephart, 2008). The abduction and flexion of the shoulder during the recovery phase of freestyle also decreases the already small amount of subacromial space in the glenohumeral joint (Borstad, 2006). The less subacromial space there is, the more vulnerable a swimmer is to the development of shoulder pain or injury (E. E. Hibberd et al., 2016). Therefore, a swimmer's dominant shoulder is more susceptible to shoulder pain than the non-dominant shoulder.

Sport-Specific Demands that Lead to Shoulder Injury

Sport-specific demands unique to swimming place swimmers at a greater risk for shoulder injury. These sport-specific demands include increased shoulder range of motion, increased adduction and internal rotation strength, and shoulder intensive training (Weldon & Richardson, 2001)

Increased Shoulder Range of Motion

Having an increased range of motion within the shoulders allows the swimmer's body to form a 180-degree angle, parallel to the surface of the water, which reduces the amount of drag during freestyle. The increased shoulder range of motion also allows for greater stroke length, which directly correlates with swim speed (Chollet, 1997). While an increase in shoulder range of motion is essential for swimmers, it also reduces the stability of the shoulder joint. The increased range of motion leads to increased capsuloligamentous laxity, which reduces the stability of the shoulder joint by decreasing the amount of force produced by the rotator cuff muscles. This inevitably leads to an unstable shoulder joint (Wirth, Lippitt, & Rockwood, 1998).

Increased Adduction and Internal Rotation Strength

Compared to non-swimmers, competitive swimmers have increased adduction and internal rotation strength (Beach, Whitney, & Dickoff-Hoffman, 1992). The swimmer's pectoralis minor and latissimus dorsi are responsible for this increase in adduction and internal rotation strength. Swimmer's adduction to abduction strength ratio is 2.05 and their internal rotation to external rotation ratio is 1.89, compared to 1.53 and 1.35 in non-swimmers, respectively (McMaster, 1999). This leads to muscular imbalances, which reduces the overall stability of the shoulder joint (Costill et al., 1985).

Therefore, training programs need to incorporate exercises that help strengthen the shoulder abductors (e.g., supraspinatus, trapezius, serratus anterior, and deltoid) and the shoulder external rotators (e.g., deltoid, infraspinatus, and teres minor) to counteract these muscular imbalances.

Prolonged Fatigue and Shoulder Intensive Training

The majority of forward propulsion is created by the shoulders, therefore, large distances can decrease the overall stability of the shoulder joint due to fatigue of the rotator cuff and scapular positioning muscles (Bak, 1996). Rotator cuff muscles and scapular positioning muscles are active throughout the entire freestyle stroke, which places them at a greater risk for fatigue (Pink, 1991). Rotator cuff muscles are responsible for keeping the humeral head inside the glenoid cavity; however, if these rotator cuff muscles are fatigued, the ability to keep the humeral head inside the glenoid cavity decreases. Therefore, the shoulder is placed in an unstable position (Pink, 1991). Abnormalities in scapular motion can lead to altered freestyle stroke mechanics, which further decreases the stability of the shoulder joint. These sport-specific demands place swimmer at a high risk for developing swimmer's shoulder at some point in their swimming career.

The Painful Shoulder

Swimmer's shoulder is a broad diagnosis for shoulder pain among competitive swimmers due to the repetitive overhead movements required during freestyle. This broad diagnosis of swimmer's shoulder consists of several injuries including subacromial impingement, scapular dyskinesis, shoulder hyperlaxity, glenohumeral internal rotation deficit, subscapular neuropathy, subluxation, and os acromiale.

Subacromial Impingement

Competitive swimmers experience a subacromial impingement when the rotator cuff, the long head of the biceps tendon, or the subacromial bursa becomes compressed and inflamed beneath the coracoacromial ligament (Page, 2011). These structures become impinged when the subacromial space narrows due to the abduction, forward flexion and internal rotation of the shoulder during freestyle. Swimmers typically experience this subacromial impingement as their hand enters the water (Matzkin et al., 2016). During 24.8% of freestyle strokes, some type of impingement occurs, which demonstrates that freestyle can place a swimmer's shoulder in an unfavorable position during approximately ¼ of the strokes that they take (Matzkin et al., 2016).

Scapular Dyskinesis

Swimmer's shoulder can also take the form of scapular dyskinesis which is an alteration in the normal resting or active position of the scapula during movement (Matzkin et al., 2016). Different scapulothoracic muscular imbalances can lead to scapular dyskinesis. A majority of the force a swimmer generates when pulling through the water comes from the adduction and internal rotation of the shoulder generated by the latissimus dorsi and the pectoralis major. The serratus anterior and subscapularis muscles are most susceptible to fatigue because they are activated throughout the entire freestyle stroke. Once fatigue sets in, the pectoralis major and minor tend to overpower the serratus anterior and subscapularis muscle. The unopposed pectoralis major places excessive strain on the anterior portion of the shoulder joint (Matzkin et al., 2016). Ultimately, these muscle imbalances lead to poor shoulder joint mechanics as well as injury.

Shoulder Hyperlaxity

Approximately 75% of competitive swimmers experience hyperlaxity of their shoulder joint. This hyperlaxity leads to an abnormal translation of the humeral head within the shoulder cavity (Martino & Rodeo, 2018). Shoulder laxity is considered an advantage for competitive swimmers up to a certain degree as it allows for a greater freestyle stroke length (Martino & Rodeo, 2018). This then correlates to greater speed and efficiency. On the other hand, an excessive amount of laxity in the shoulder joint can lead to rotator cuff muscle fatigue, and even injury. Swimmers who display a dropped elbow and a lack of body roll often have an excessive amount of hyperlaxity in the shoulder joint (Matzkin et al., 2016). Swimmers exhibit a dropped elbow when they pull their hand backward in a relatively flat position to avoid excessive internal rotation of the shoulder (Figure 1). Even if there is pressure being placed on the water by the hand, the hand will slip backward without catching any water. This is not ideal, as swimmers want to catch as much water as possible to propel themselves forward.

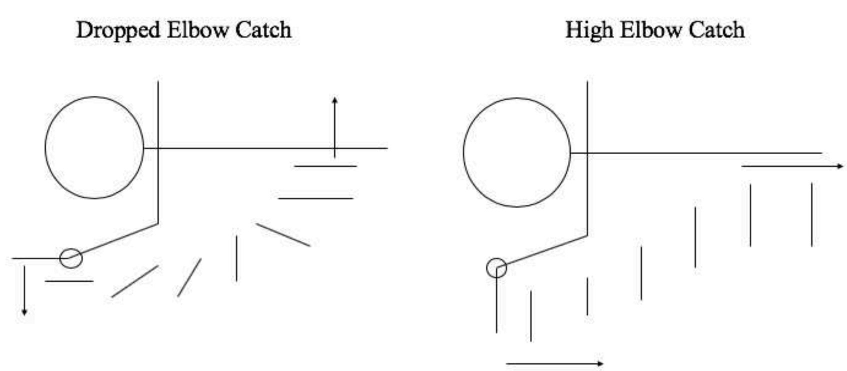

Figure 1. Dropped Elbow Catch vs. High Elbow Catch

Glenohumeral Internal Rotation Deficit (GIRD)

Glenohumeral internal rotation deficit (GIRD) occurs when the dominant shoulder exhibits less internal rotation compared to the non-dominant shoulder (Matzkin et al., 2016). Swimmers exhibit approximately 10° more external rotation and 40° less internal rotation than non-swimmers. This deficit produces a force anteriorly on the humeral head causing the shoulder capsule to become unstable (Matzkin et al., 2016). Several studies show a correlation between GIRD and posterior shoulder tightness (Matzkin et al., 2016; Tyler, Nicholas, Roy, & Glein, 2000). One study found that for every four degrees of internal rotation, there was a one-centimeter reduction in passive horizontal adduction (Tyler et al., 2000). This posterior shoulder capsule tightness decreased internal rotation, and increased external rotation is due to the basic biomechanics of freestyle. Most swimmers prefer to breathe on their dominant side which in turn causes more external rotation toward the dominant shoulder and causes the non-dominant shoulder to compensate (Matzkin et al., 2016).

Suprascapular Neuropathy

Suprascapular neuropathy occurs when the suprascapular nerve gets caught underneath the suprascapular ligament during freestyle. Since the subacromial space is already small, the nerve can easily get caught underneath the suprascapular ligament. Some common signs and symptoms include, decreased abduction strength, decreased internal rotation strength, shoulder weakness, atrophy, aching, or burning in the posterolateral aspect of the shoulder (Walsworth, Mills, & Michener, 2004). Swimmers will exhibit decreased abduction strength and decreased internal rotation strength because the suprascapular nerve innervates both the infraspinatus and supraspinatus muscles (Matzkin et al., 2016).

Subluxation

Subluxation or the partial displacement of the humeral head is common among competitive swimmers due to the increase in shoulder laxity, adduction strength, and internal rotation strength. When a subluxation occurs, it can cause damage to the labrum. The labrum of the shoulder joint can eventually become frayed or even detached. If this happens, it could get caught during shoulder motion, causing pain (Matzkin et al., 2016). Competitive swimmers are at risk for subluxation when they dive off the blocks due to the position of the arms and shoulders. Diving into the water hand, and head first, with arms fully extended, places them in an unstable position (McMaster, 1986).

Os Acromiale (OA)

Failure of the acromial apophysis to fuse causes an os acromiale (OA) (Frizzero et al., 2012). The acromial apophysis originates from four ossification sites including, the basiacromion, meta-acromion, meso-acromion, and pre-acromion (Kurtz, Humble, Rodosky, & Sekiya, 2006). These four ossification sites generally fuse by age 18-25 and the greatest number of OAs are meso-acromial (Kurtz et al., 2006). Many overhead athletes tend to reach an elite level between the ages of 18 and 25; therefore, it is useful to diagnose OA and plan an effective therapeutic plan for those athletes. It is possible to diagnose OA using an ultrasound (Frizzero et al., 2012). OA is usually asymptomatic; however, when it is painful the symptoms look similar to those of a subacromial impingement (Frizzero et al., 2012). The failure of an ossification site to fuse results in less subacromial space available during shoulder flexion. This is critical for swimmers, as flexion is a large portion of the swim stroke. However, this is an uncommon cause of swimmer's shoulder, as OA only occurs between one percent and fifteen percent of the time in the general population (Frizzero et al., 2012). The image below shows the four centers of acromial ossification (Frizzero et al., 2012) (Figure 2).

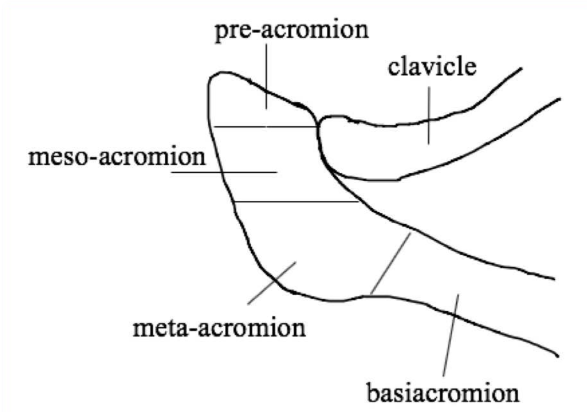

Figure 2. Four Ossification Centers of the Acromion

Preventative Measures

In the pool, swimmers should focus on bilateral breathing and avoid picking their head up to breathe to prevent swimmer's shoulder. Swim instructors and coaches should emphasize bilateral breathing early on in a swimmer's career. Coaches should also keep an eye out for unilateral breathing as well as any alterations in stroke mechanics that could be indicative of shoulder pain such as a dropped elbow, excessive body roll, or hand-placement away from the midline. Also, to prevent the likelihood of developing a rounded forward posture coaches should counteract these muscular imbalances by implementing a land-based prevention program as soon as a swimmer's competitive career begins.

The rehabilitation protocol for swimmers' shoulder is fairly similar amongst the rehabilitation world, although some swim programs don't put these protocols into motion until the swimmer has been injured. With swimming consisting of repetitive motions and being a shoulder dominant sport, it is imperative for swimmers, coaches, and athletic trainers to be proactive and start taking preventative measures before the swimmer becomes injured. Since the number of swimmers who will experience shoulder pain at some point in their career is so large, it is safe to assume that every swimmer will experience some sort of shoulder pain. Therefore, the swimming community as a whole should be proactive by emphasizing preventative measures starting from a young age.

Swimmers and coaches can be proactive by implementing some basic shoulder stretches and strengthening exercises into their everyday workouts. Swimmers commonly focus on stretching the anterior part of the shoulder capsule by fully extending the shoulder against a wall. However, it is important to also stretch the posterior capsule as overstretching the anterior capsule can worsen the muscular imbalances that lead to impingement (Matzkin et al., 2016). Some good stretches for the posterior shoulder capsule include the sleepers stretch or the crossover stretch. During the sleeper stretch, the athlete would lie on the symptomatic side, place the elbow at a 90° angle, and the other arm is used to gently internally rotate the symptomatic arm until a stretch is felt on the posterior side of the shoulder capsule (Matzkin et al., 2016).

In addition to stretching the posterior shoulder capsule, it is also important for the swimmer to stretch the pectoralis minor muscle as this will help to reduce a swimmer's rounded forward posture. A few good stretches for the pectoralis minor would be the corner stretch or lying on a foam roller down the center of the back with arms outstretched to the side (Kluemper, Uhl, & Hazelrigg, 2006). During the corner stretch the swimmer would stand in a corner with one foot in front of the other, hands and elbows would be placed at a 90° angle on the wall, and the athlete would slightly lean forward until a small stretch is felt in the anterior shoulder and chest. Consistently performing this pectoralis minor stretch on the foam roller can help to reduce forward posture in competitive swimmers (Kluemper et al., 2006).

Not only is it important to stretch the muscles in the shoulder, it is also important to strengthen them as well. Some common strengthening exercises that coaches should implement early on in a swimmer's career are scapular retraction (rhomboids and trapezius), external rotation (deltoid, infraspinatus, and teres minor muscles), shoulder flexion (deltoid, and pectoralis major), Y/T/W's (serratus anterior, trapezius, rhomboids, and supraspinatus), horizontal row (infraspinatus and teres minor muscles), military press (serratus anterior, subscapularis, latissimus dorsi, pectoralis major, biceps brachii, triceps brachii, and deltoid muscles), and push up with a plus (serratus anterior and subscapularis muscles) (E. Hibberd, Oyama, Spang, Prentice, & Meyers, 2012; Kluemper et al., 2006; Matzkin et al., 2016). Swimmers should be completing these shoulder strengthening exercises along with the stretches mentioned above on a daily basis, especially when the distance and intensity during workouts increase. Doing these stretches and exercises can help reduce a swimmer's risk of developing swimmer's shoulder and a rounded forward posture (Figure 3).

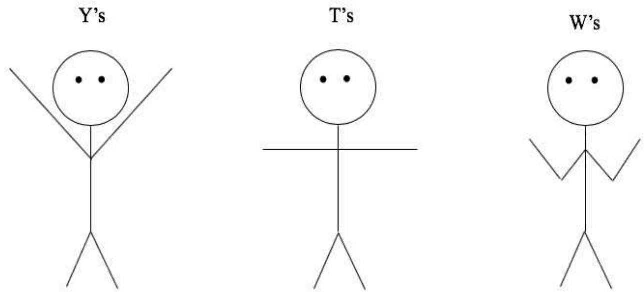

Figure 3. Y/T/W's Exercise

Typical Rehabilitation Protocol

Both preventative and rehabilitation programs for swimmer's shoulder are fairly consistent amongst the rehabilitation world. However, these programs need to be implemented more before a swimmer becomes injured as these programs have been proven to reduce shoulder pain and a rounded forward posture. Kluemper, Uhl, and Hazelrigg (2006) specifically looked at the effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. The swimmers went through a 6-week stretching and strengthening program in which they did the exercises three times a week (Kluemper et al., 2006). Each day they completed three exercises with a TheraBand including scapular retraction, external rotation, and shoulder flexion for the lower trapezius. The swimmers also completed three different stretches including lying supine with a foam roller running down the middle of their back (anterior chest muscles), partner-assisted pectoralis major stretch and partner-assisted pectoralis minor stretch (Kluemper et al., 2006). The researchers found that the 6-week training program of stretching the anterior shoulder muscles and strengthening the posterior shoulder muscles slightly reduced the swimmer's forward posture (Kluemper et al., 2006).

Another study examined the effects of a 6-week strengthening program on the shoulder and scapular-stabilizer strength and scapular kinematics among Division I collegiate swimmers. The protocol was completed three times a week for 6 weeks. The protocol program included strengthening exercises using a resistance band- T's (scapular retraction), Y's (scapular retraction with upward rotation), W's (shoulder flexion and external rotation), low rows, throwing acceleration and deceleration, scapular punches, shoulder internal rotation at 90° abduction, and shoulder external rotation at 90° external rotation. The swimmers also completed the corner stretch and the sleepers stretch as well. The researchers found that after the 6-week program, the swimmers had increased scapular internal rotation, protraction and elevation (E. Hibberd et al., 2012). When developing a preventative program, coaches should avoid any exercises that may overlap with training done in the weight room or the pool. Basic preventative protocols for swimmer's shoulder should look similar to the two studies mentioned above.

CHAPTER 3

FURTHER RESEARCH

Most of the research literature has focused on how breathing affects stroke mechanics. More research needs to be done on how breathing affects a swimmer's risk for shoulder injury and if there are any major differences between unilateral and bilateral breathing. For many coaches, it is difficult to identify any biomechanical alterations in freestyle immediately when they have several swimmers in the pool at a time and only one or two coaches on deck at a time. Today, many swimmers wear an Apple Watch during practice to monitor their heart rate, distance swam, calories burned, splits, etc. The Apple Watch can detect which stroke the swimmer is currently swimming and how fast they are swimming. Researchers should develop an app for the Apple Watch that would immediately detect any alterations in the swimmer's stroke mechanics and give immediate feedback to the swimmer. The sooner a swimmer can detect any alterations in their stroke mechanics, the quicker they can fix it, and the less likely they are to get injured.

Another area of research that should be focused on is different preventative measures that can be taken early on in a swimmer's career. Most programs don't implement stretches or strengthening exercises until after the swimmer has been injured. After the swimmer is injured it is too late and athletic trainers or physical therapists take over with a rehabilitation protocol. Although, once the swimmer is better these preventative exercises are important to complete to prevent the likelihood of reinjury. Athletic trainers should take a mandatory baseline, midseason, and end-season measurements for every swimmer, especially in middle school, high school, and college. These measurements are important so athletic trainers can specifically target what each swimmer needs to work on to avoid shoulder injury. Some swimmers may need more external rotation or internal rotation work, postural work, etc. This way coaches and athletic trainers can work together to prevent shoulder injuries early on and throughout a swimmer's entire career.

CHAPTER 4

CONCLUSION

Overall, swimmer’s shoulder is a very prominent issue in the sport of swimming as all swimmers have a high risk for developing a shoulder injury, especially female swimmers (Harrington et al., 2014). Due to the demands of swimming, swimmers typically breathe unilaterally, have increased internal rotation and adduction strength, increased shoulder range of motion, and forward posture, which is especially evident in the dominant shoulder. Therefore, the dominant shoulder has a greater risk of injury than the non-dominant shoulder due to unilateral breathing. It is important to start an exercise prevention program early on in a swimmer’s career to decrease their risk for developing swimmer’s shoulder and to counteract these muscular imbalances. Coaches should keep an eye out for any alterations in stroke mechanics that could be signs of shoulder pain. Healthy shoulders are a competitive swimmer's biggest asset, therefore it is imperative to keep their shoulders healthy and in good condition.

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